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U. S. Army Chemical Corps Research and Development Command
U. S. ARMY CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES
Army Chemical Center, Maryland

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TO: Commander Armed Services Technical
Information Agency, ATTN: TIPCR
Arlington Hall Station,
Arlington 12, Virginia

Insert the attached Table 1 as page 26 of the Unclassified report, CRDLR 3062, "Development of a Nonhazardous Technique for Quantitatively Evaluating the Inhalation effectiveness of CW Munitions" (U). The authors are Frank C. Whitney and Mitchell Penn. This document was forwarded to you on 21 August 1961.

FOR THE COMMANDER:

Harold L Anderson

HARROLD L. ANDERSON
Chief, Publications Branch
Directorate of Technical Services

U. S. Army

Chemical Research and Development Laboratories

Technical Report

CRDLR 3062

Development of a Nonhazardous Technique for Quantitatively Evaluating the Inhalation Effectiveness of CW Munitions

by

Frank C. Whitney
Mitchell E. Penn

August 1961

ARMY CHEMICAL CENTER, MD.

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CRDLR 3062

DEVELOPMENT OF A NONHAZARDOUS TECHNIQUE FOR QUANTITATIVELY EVALUATING THE INHALATION EFFECTIVENESS OF CW MUNITIONS

by

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FOREWORD

This investigation was authorized under Task 4C04-15-029-04, Dissemination Research on Training and Test Agents (U). The work was started in January 1957 and completed in January 1959. The experimental data are recorded in Technical Command Notebook 4937 and CWL Notebook 6219.

Acknowledgments

The authors wish to thank Mr David Howes, statistician of the U. S. Army Chemical Corps ENCOM, for his generous assistance in reviewing certain parts of the data contained in this report. Acknowledgment is also made to Dr David Rosenblatt of the Biochemical Research Division, Directorate of Research, for suggesting the improved analysis of Uvinul 400 by the Beckman spectrophotometer, to Mr Julius Miller of the Weapons Research Division, Directorate of Research, for developing the analysis of Uvinul 400 by the Beckman spectrophotometer, and to the Analytical Research Division, Directorate of Research, for developing the chemical method of analysis of Uvinul 400.

DIGEST

The objective of this investigation was to develop a technique for quantitatively evaluating the inhalation effectiveness of CW munitions as part of the overall CARAMU program.

In this connection, a method for instantaneously generating a nontoxic cloud of fine aerosol in a nonhazardous manner was developed. A "puff"-type, electrically activated grenade containing a mixture of 2,4-dihydroxy benzophenone and a pyrotechnic fuel was designed and tested.

The oronasal mask, developed under the Protective program of these Laboratories, was employed as one of the primary elements of the system.

Data obtained from laboratory experiments on the fine aerosol cloud-oronasal mask system are described.

It was concluded that the "puff"-type grenade-oronasal mask system provides a technically feasible method for quantitatively evaluating the inhalation effectiveness of the cloud which would be produced by CW munitions. The system could be employed as part of the CARAMU program.

CONTENTS

DEVELOPMENT OF A NONHAZARDOUS TECHNIQUE FOR QUANTITATIVELY EVALUATING THE INHALATION EFFECTIVENESS OF CW MUNITIONS

I. INTRODUCTION.

A. Object.

The purposes of this investigation were to provide a nontoxic, nonlethal, smoke cloud that would simulate a cloud produced by the functioning of a toxic munition and to evaluate the technique of using this cloud in conjunction with the oronasal mask for quantitatively estimating the inhalation dosage of CW agents.

B. Background.

The Chemical Corps has a continuing task of assessing the casualty effect of its toxic chemical munitions. Any method of determining this casualty effect must at least estimate the amount of toxic agent (gas or aerosol) inhaled by exposed personnel.

To measure the total dosage of a simulated toxic aerosol inhaled by human test subjects, an oronasal mask was developed by the Protective Development Division of these Laboratories under Subproject 4-80-02-030-04, Design and Development of Protective Mask Components (U). The mask has a filter of type-5 cellulose-asbestos material and is pleated to give low resistance to breathing. The filtration surface area is about 100 sq cm. A band of adhesive tape on the periphery of the filter attaches the mask to the face, around the nose and mouth.

This filter mask appeared to be a satisfactory way of retaining aerosol to which personnel had been exposed. However, a complete system for determining casualty rates required that a munition simulant be devised. The complete system must then be tested to determine its adequacy.

The requirements for this simulant were as follows:

1. The simulant must function completely in an instantaneous manner.

2. The dispersion mechanism should be nonhazardous to personnel in the immediate vicinity.

3. The smoke produced should be nontoxic.

4. The particle size of the aerosol produced should be between 2μ and 5μ. The upper size limit ensures that the physical properties of the aerosol are similar to those of a gas. The lower limit was imposed because the type-5 filter paper's filtering efficiency decreases rapidly when liquid particles are less than 2μ in diameter.

5. The aerosol produced can be analyzed, preferably by some rapid simple method.

II. EXPERIMENTAL.

A. Description of Oronasal Mask.

1. The cellulose-asbestos paper in the filter of the oronasal mask (figure 1) was originally developed by the Chemical Corps for protective masks. Known as C. W. S. type 5, it consists of fine asbestos fibers mixed with coarse cellulose fibers to give mechanical strength and to support the asbestos. The asbestos does most of the filtering; its efficiency is initially high and increases as the mask is used.

The type-5 filter is composed of esparto-hemp fibers, 93%; asbestos, 5%; and fungicide, 2% (percentages are approximate). Gauze scrim on the front and back of the filter reinforces it and holds it together. Pleating the filter paper in areas of approximately 100 sq cm provided what was believed to be satisfactory resistance to airflow (table 1).

TABLE 1

RESISTANCE OF TYPE-5 FILTER PAPER TO AIRFLOW*

Airflow	Resistance of type-5 filter paper
cm/min	mm water/100 sq cm
32	7
85	14
150	23

* Shoemaker, C. J., and Todd, N. W. Development of an Oronasal Sampling Device. Protective Development Division. Unpublished Report.

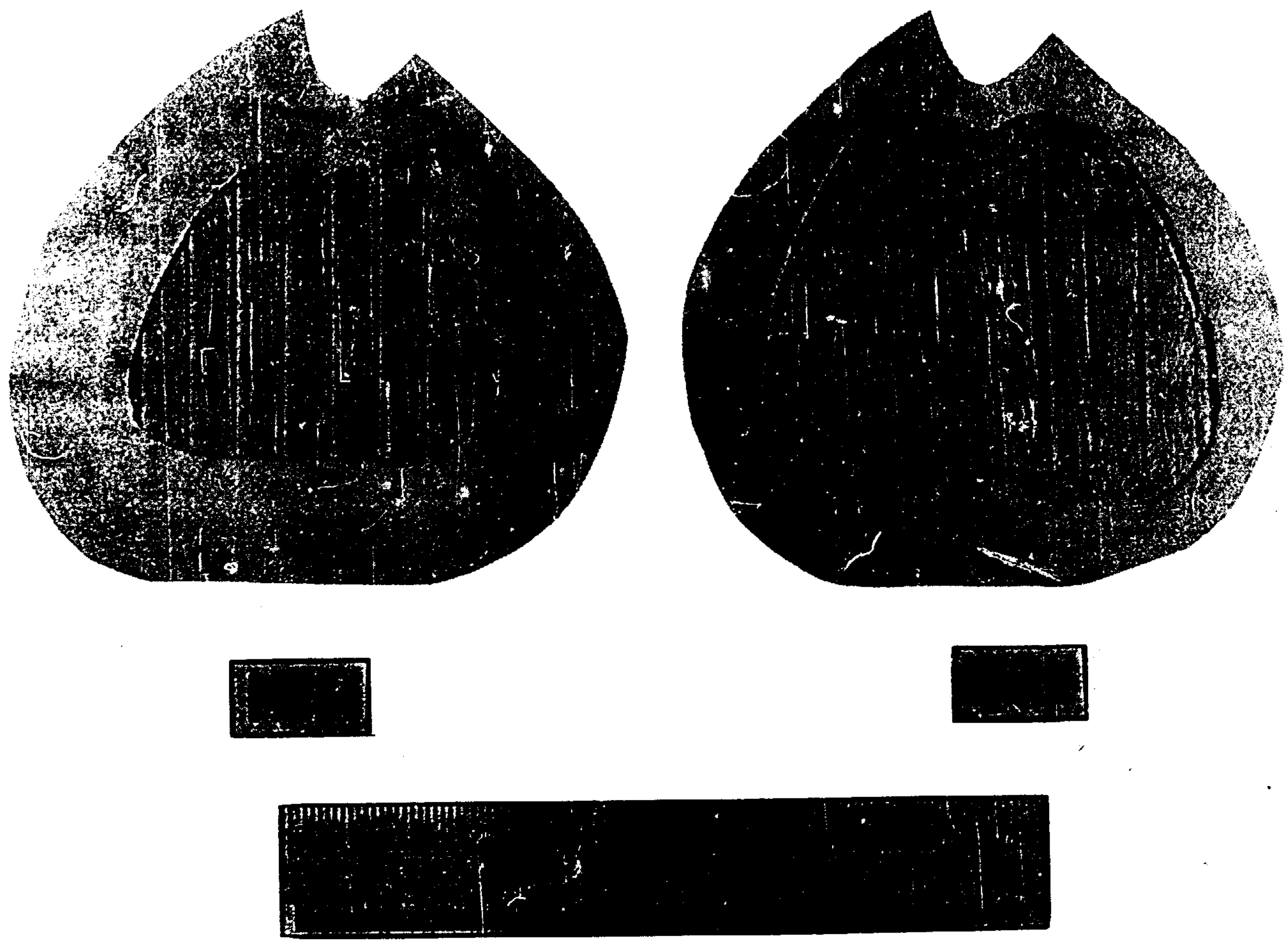

FIGURE 1

ORONASAL MASK

B. Smoke Materials and Dissemination Methods.

At the beginning of this investigation, several materials and methods were studied in an attempt to produce a suitable aerosol to use in testing the oronasal mask.

1. Explosive Dissemination.

The use of low-brisance explosives was investigated as a dissemination method. Black powder, loaded into nonmetallic components, disseminated both liquid and impregnated solids as aerosols. Since the dissemination efficiency was extremely low with both liquids and solids, this method was abandoned with the acquisition of an instantaneous pyrotechnic grenade.

2. Auramine Hydrochloride.

An instantaneous or puff grenade, which apparently disseminated auramine hydrochloride dye adequately, was devised. The construction of the grenade is described below.

Fifty grams of dry smoke mixture were poured into a smoke grenade can; the mixture was composed of the dye, potassium chlorate, thiourea, and sodium bicarbonate—all granulated with a collodion binder. An electric squib was inserted into the mixture. Slits in the side of the can, allowing a quick easy outlet for the smoke cloud, were closed with tape.

Upon functioning, a large puff of smoke was produced through the side openings; no shrapnel was produced. Satisfactory results were obtained in a few preliminary experiments, but testing of this item was stopped because a toxicity report* warned that auramine hydrochloride dye might be a carcinogen.

3. Uvinul M40 and Uvinul 400.

The Uvinul products, which are ultraviolet-light absorbers, are a series of substituted benzophenones supplied commercially by Antara Chemicals, New York, N. Y. These materials absorb ultraviolet rays from

* Disposition Form from Chief, Toxic Information Center, Directorate of Technical Services, to Mitchell E. Penn, Weapons Research Division, Directorate of Research, 1 August 1957, subject: Toxicity of Auramine Hydrochloride [CMLRD-CW-T(T1-8)].

200 mμ (2,000 Å) to 400 mμ (4,000 Å), the threshold of visible light. They are stable to both ultraviolet and visible light and are not fluorescent. Most important, as indicated by all published toxicological studies, these compounds seem to cause no toxic or irritant reactions.

Since Uvinul M40 (2-hydroxy-4-methoxy benzophenone) was available in these Laboratories, this was the first compound upon which thermal-dissemination studies were conducted. After thermal-dissemination techniques that could be used to disseminate this material were established, a sample of Uvinul 400 (2,4-dihydroxy benzophenone), a similar material having a higher melting point, was procured. This latter material was equally satisfactory.

The puff grenade remained essentially the same as the grenade devised to disseminate auramine hydrochloride except for the minor modification of moving the slit openings to the bottom of the grenade can.

Uvinul 400 was selected as the material to be used in future tests. It is a cream-colored crystalline powder that has a melting point of 145°C (adequate for any anticipated storage conditions). It has an absorption peak of about 293 mμ, which can be used for analysis.

C. Smoke Grenades With Uvinul 400.

A number of experimental grenades was made and tested. The smoke mixture consisted of three active components; i.e., Uvinul 400, potassium chlorate, and thiourea. These materials were intimately mixed, first in the dry state, then with a collodion solution. This mixture was then passed through a no. 14 screen to obtain a granulated product, and the acetone was evaporated to dryness. Granulation helped to promote better burning of the smoke mixture. The grenade formulation used in this work is presented in table 2.

Fifty grams of this smoke mixture were wrapped, with an electric squib, in a bag of aluminum foil. Wrapping the squib in the pyrotechnic mixture proved more successful for producing uniform grenade functioning than any arrangement tried. The charge was placed in a solid-top grenade that had a 1/2-inch hole in the base from which four axial slots extended almost to the edge of the can. These openings were taped closed (figures 2 and 3).

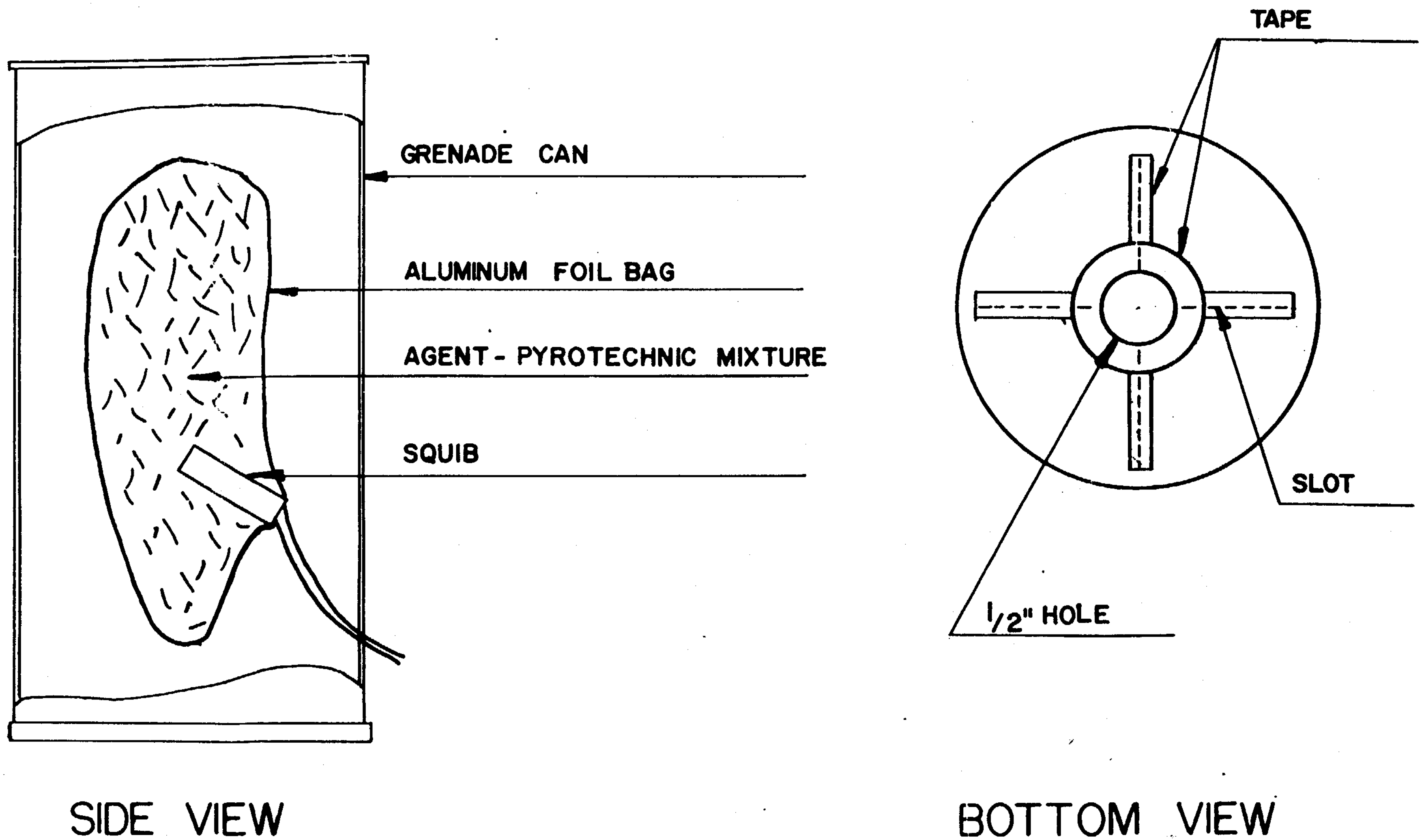

FIGURE 2

VEHICLE DESIGN

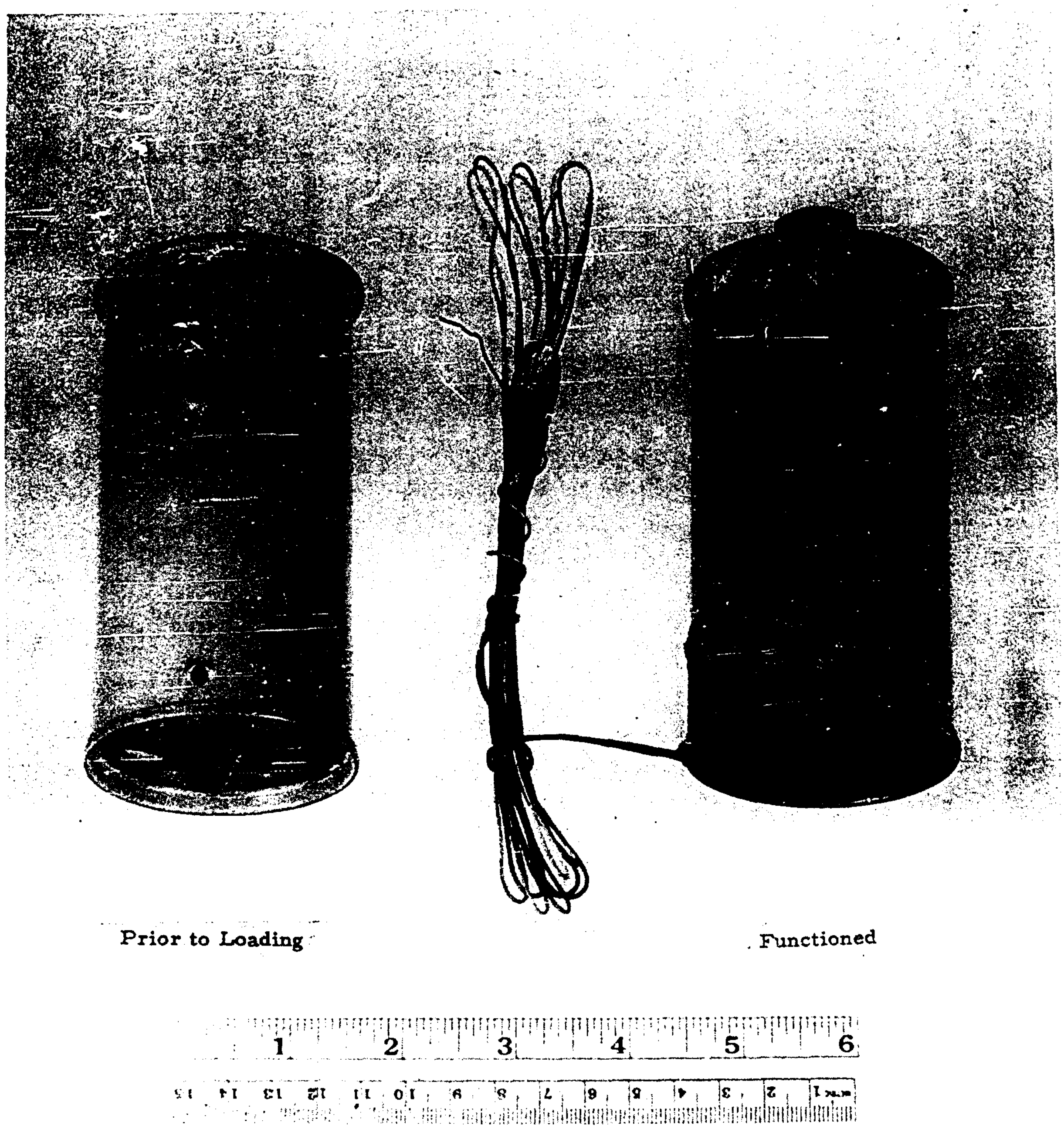

FIGURE 3

PUFF GRENADE

TABLE 2

GRENADE FORMULATION

Components	Weight	Per cent by weight
	gm	
Uvinul 400	26.9	53.8
Potassium chlorate	13.0	25.9
Thiourea	9.3	18.6
Collodion*	0.8	1.7
	50.0	100.0

* 8% Cellulose nitrate, 22 gm/100 gm of mix.

The electric squibs used initially were the M1 and M5 vented squibs, but they were unsatisfactory because their vents clogged. The squibs malfunctioned either because the ignition material deteriorated or because the pyrotechnic mixture was packed on top of the ignition material. To avoid the erratic functioning of the vented squib, a nonvented squib was used.

Toxicity tests conducted by the Toxicology Division of these Laboratories on animals (dogs, rabbits, and rats) showed that an aerosol of Uvinul 400 disseminated from a smoke grenade was nontoxic. Tests on animals, not protected by masks but exposed to a high concentration of smoke for periods up to 1 hour and subsequently kept under observation, showed that the pyrotechnic smoke had a very low order of toxicity.*

Several reports of toxicological tests conducted by commercial sources at the request of Antara Chemicals also indicated extremely low toxicity or irritation from the substituted benzophenones.

* Unpublished toxicity data from Toxicology Division, Directorate of Medical Research, CRDL.

D. Procedure.

The type-5 filter of the oronasal mask was evaluated to determine its performance with aerosols produced by the puff grenade under various conditions of airflow rate and aerosol concentration.

1. Determination of Aerosol Particle Size.

a. Cascade Impactor.

The particle sizes of the Uvinul aerosols were determined by a modified, four-stage, cascade impactor (C. F. Casella & Co., Ltd., London). The standard impactor equipped with four stages upon which the aerosol particles impact according to size was modified to include an aerosol filter as a fifth stage.

Unfortunately, the cascade impactor was designed to measure particle diameters ranging from about 1μ to about 10μ. The particles produced in these experiments were, to a large extent, smaller than could be sampled by the experiment. Extrapolation from curves with minimal data was, therefore, required, resulting in estimates of MMD's, which do not have high precision or accuracy. These results were analyzed by plotting them on logarithmic probability paper. A typical result is shown in figure 4.

From these data, the average particle diameter of the Uvinul aerosol was estimated to be about 0.5μ.

b. Electron Microscope.

An attempt was made to obtain particle-size data with the electron microscope, but such a procedure is fraught with problems. For example, special settling chambers and slides must be prepared according to specified procedures. Even after some small samples were obtained, they vaporized in the electron stream of the microscope. It appeared that a great deal of experimental work would be required to obtain a stable replica of the aerosol on the slide. Also, the entire sampling procedure seemed to be developing a high degree of complexity. This approach was, therefore, abandoned because it was not worth the effort necessary to solve these problems.

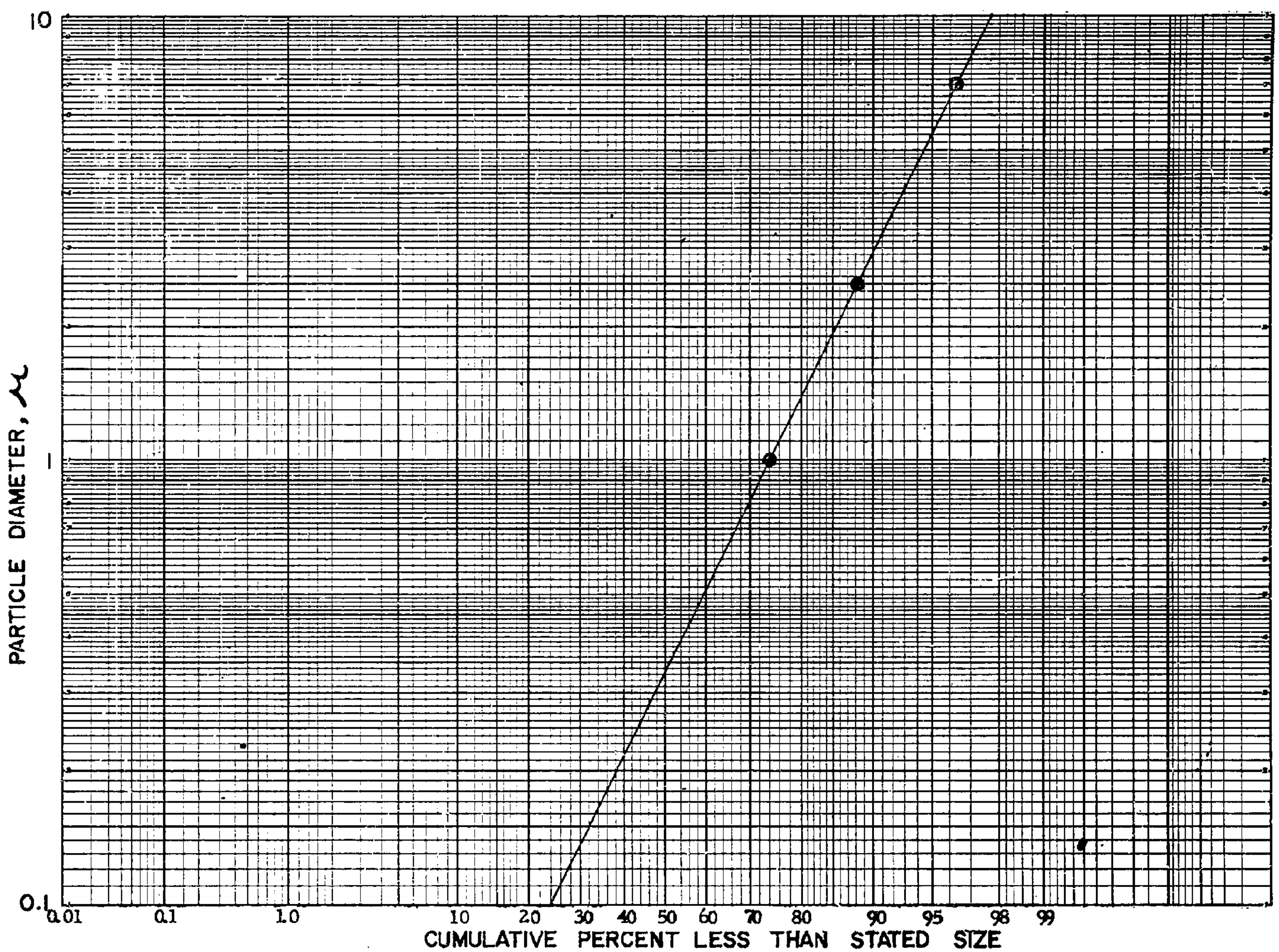

FIGURE 4

PARTICLE DIAMETER VERSUS CUMULATIVE PER CENT LESS THAN STATED SIZE

2. Test Procedure.

a. Setting Up Filters for Testing.

Since the oronasal mask is composed solely of the type-5 filter material, the terms type-5 filter and oronasal mask are used interchangeably in the following tests. Samples representative of stock supplies of the type-5 material, both pleated and smooth single layers, were taken from finished masks and from stock rolls and were tested for filtration efficiency by clamping specimens in a circular steel jig having a 3-inch-diameter opening, a surface area of about 40 sq cm (figures 5 and 6). To obtain higher linear velocities through the filter, cardboard disks containing suitable openings were clamped both in front and behind the filter.

This filter was then backed by a 3-inch disk of high-retentivity, glass-fiber filter (E9), which retained any particles passing through the type-5 filter. A disk of copper screening was used as a spacer between the type-5 and E9 filters. Rubber gaskets around the filter sealed its edges. The jig was connected by rubber tubing to the suction pump. The proper airflow was ensured by use of a critical orifice.

To obtain more data per test, two to six test jigs were connected to a manifold fabricated from 1-inch-diameter brass tubing. The manifold was then connected to the vacuum pump as indicated in the preceding paragraph. An airflow of 17 l/min was normally maintained through each manifold.

Airflow through the cascade impactor (17.5 l/min) was controlled by a critical orifice.

In several tests, instead of sampling by constant flow, breather pumps were used as the source of suction to simulate the breathing pattern (inhale-exhale) of a human being. In these runs, the pumps were connected to the manifolds mentioned previously. The breather pumps were set for an airflow of 25 l/min, at a breathing rate of 30 cycles per minute.

b. Smoke Cloud and Sampling.

Tests were conducted in a large Quonset hut having a capacity of 10,000 cu ft. Air was circulated by a 24-inch-diameter pedestal fan. The procedure for a specific test is given below.

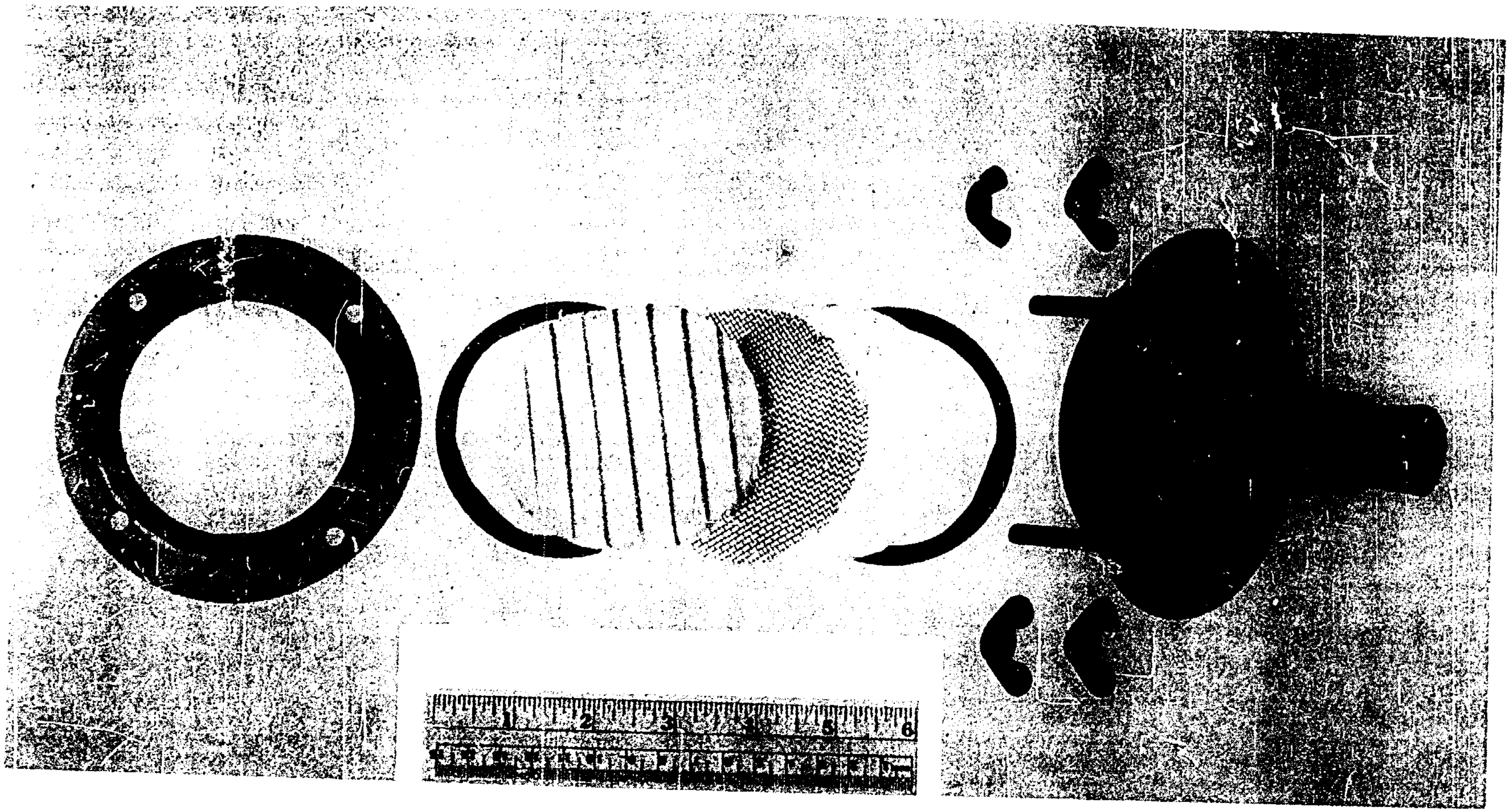

FIGURE 5

TEST JIG

FIGURE 6

TEST JIG

The jigs that held the filters were connected, singly and on manifolds, to the suction lines in the chamber. To prevent impingement of aerosol particles on the filters during dispersion of the smoke cloud, the filters' surfaces were faced away from the grenade and fan. Experience has shown that such an arrangement is adequate. A smoke grenade containing Uvinul 400 was placed on its side on the floor of the chamber and was functioned electrically by a blasting machine outside the chamber. Five minutes after functioning, the aerosol cloud was uniformly dispersed by the fan in the chamber; the suction pumps were started, and measured volumes of smoke were drawn through the filters in the jigs. At this time also, samples used for determining particle size were taken by the cascade impactor. Samples were taken for specific times; i.e., 20 and 30 seconds for the cascade impactor and 15 minutes for the jigs.

The smoke in the chamber was sampled by an automatically timed electrostatic precipitator using three sampling cylinders. Smoke was drawn through each cylinder at a rate of 85 l/min for 3 minutes. Sampling was begun 5, 9, and 13 minutes after the grenade was functioned. At the end of the test (total time, 20 minutes), the chamber was thoroughly ventilated, and the samplers were removed, capped, and submitted for analysis.

III. RESULTS.*

A. Filtration Efficiency of Oronasal Mask.

The filtration efficiency of the type-5 filter was found by analysis of the amount of Uvinul on each filter, type-5 and E9. It was calculated by the following equation:

$$\text{Per cent efficiency} = \frac{A \times 100}{A + B}$$

where

A = Amount of Uvinul on type-5 filter (gm)

B = Amount of Uvinul on E9 filter (gm)

A third filter (also an E9) was used in several of the early runs to determine if particles were passing through the second filter. No Uvinul was ever found on the third filter; hence, it was concluded that the first E9 filter retained all the aerosol particles that penetrated the type-5 filter.

* See appendix A, table 1, for a complete tabulation of results.

Linear velocity, centimeters per minute, is the basis used for filter comparison. Linear velocity is calculated by dividing mass-flow rate by the filter area utilized.

Tests were conducted at linear velocities ranging from about 50 to 1800 cm/min, with the greatest number being conducted in the range from about 60 to 300 cm/min, which corresponds in this experiment to a human who breathes from 6 to 32 l/min. *

Results of all these tests revealed that filtration efficiency shows no increase with linear velocity and that the type-5 filter paper had a filtration efficiency of approximately 80%.

B. Efficiency of Uvinul Puff Grenade.

The efficiency, or percentage of agent returned, of the Uvinul 400 smoke grenade was found to be low, which is not unusual in grenades of this sort. Grenade efficiency was determined by plotting the concentration of Uvinul found in three samples of smoke (electrostatic precipitator tubes) against time and by extrapolating the curve to zero time. This zero-time concentration was then compared to the amount of Uvinul (26.9 gm) in the pyrotechnic mixture of the grenade, and the per cent efficiency was calculated as follows:

$$\frac{C_o\ (\text{mg/l}) \times 2.83 \times 10^5\ (\text{liters per chamber} \times 100)}{2.69 \times 10^7\ (\text{mg per grenade})} = C_o \times 1.05 \begin{pmatrix}\text{grenade efficiency in} \\ \text{per cent agent returned}\end{pmatrix}$$

where

C_o = concentration at functioning time

The 26 grenades fired had an average agent return of 10% with a variance of 4.5%.

---

* See appendix A, table 2, for chart showing typical breathing rates of man.

C. Evaporation of Uvinul Aerosol.

To determine whether any significant portion of the Uvinul collected on the filter paper could evaporate when fresh air passed through the sample, two aeration tests were conducted. In these tests, two manifolds that contained filters sampled the smoke cloud. Conditions, such as sampling time, total volume of air sampled, and position of manifolds, were kept as constant as possible for each unit. One of these units then sampled fresh air under equivalent conditions to those above.

The results given in table 3 show no marked loss of Uvinul after aeration procedures.

TABLE 3

WEIGHT LOSS OF UVINUL RESULTING FROM AERATION

Test	Weight on filter after aeration / Weight on nonaerated filter
15	1.2
17	0.95

D. Blowoff.

To determine whether any blowoff (loss resulting from the exhale portion of a breathing cycle) occurs, tests using breather pumps were conducted. The breather pump, which is designed to simulate a person's breathing, is a motor-driven apparatus having two cylinders in which pistons draw 25 liters of air each minute in 30 inhale-exhale strokes. These tests, conducted at a high flow rate and high smoke concentration, showed that blowoff of particles was insignificant or negligible. The results of these tests are shown in table 4.

E. Grenade Surveillance.

Some grenades were placed in storage at 130°F for over 100 days for surveillance testing. Both the dissemination efficiencies and the burning characteristics of these grenades were not adversely affected by storage. The results of these tests are presented in table 5.

TABLE 4

EFFECT OF BLOWOFF

Test	$\frac{\text{Weight on filter after full breathing cycle}}{\text{Weight on filter using only inhale stroke}}$
18	——
19	0.95
20	1.1
21	0.94
22	1.0
23	0.90
24	0.95
25	0.89

TABLE 5

EFFICIENCY OF GRENADE AFTER STORAGE

Test	Storage conditions	Grenade efficiency %
18	130^{o}F for 102 days	10
19	130^{o}F for 102 days	13
20	Ambient for 45 days	11

F. Squib Requirement.

Ventilated M1 and M5 squibs were used in the Uvinul and some of the earlier grenades. The squibs were inserted in the aluminum-foil bag of granulated smoke mixture within the grenade. In several cases, the firing of the squib was sluggish, or failed entirely. Examination revealed that the granulated mixture had entered the vent holes in the body of the electric squib and clogged the passage, thus interfering with proper functioning of the squib. Nonventilated squibs were, therefore, substituted in these nonfunctioning grenades. The grenades functioned well in all cases; i.e., they produced a sharp report, an immediate, well-dispersed, smoke cloud, and no residual burning in the grenade can. Six grenades made with these squibs were tested after storage at ambient temperature (50°F to 80°F) for 6 to 8 weeks, and all functioned properly. The squib adopted was identified as: squib, electric, closed, MIL-STD S10432.

Runs 22, 23, 24, and 25 were carried out employing nonventilated squibs in the grenade.

G. Chemical Analysis.

The chemical analysis for the substituted benzophenone first used depended upon absorption in the ultraviolet region, at 293 mμ. Although this analysis was originally found to be adequate by the analytical group, extremely high and variable blanks began to appear when it was used. This analytical procedure was, therefore, dropped in favor of a color-developing coupling reaction (method 1, appendix B) that gave relatively satisfactory results.

Simultaneously, a limited effort was expended in an attempt to improve the analysis. A successful test was developed (method 2, appendix B) that had a much higher precision and was more easily accomplished than the one used in this program. Unfortunately, this improved analysis was developed too late to be used in this investigation, but it is now available for use in any future tests.

IV. DISCUSSION.

The requirements were met successfully. An instantaneously acting dissemination system was devised that has a nonlethal action and produces a nontoxic aerosol. The particles are small enough to behave like a gas, yet they can be filtered by the oronasal mask. Rapid and accurate methods of analysis are available to determine quantities of aerosol collected.

The variations in the results are assumed to be mainly caused by problems encountered in the analysis of the aerosol. These problems, which arose in the original chemical analysis, seemed to stem directly from the filter paper. After running various confirmatory tests, it was decided that the filter paper was adding something to the solution that caused erratic results at the frequencies used.

The chemical analysis used to replace the original test was more complicated and had a lower sensitivity but seemed adequate for the experimental samples obtained.

The chemical analysis finally developed and recommended for use for future tests requires the addition of a small amount of caustic, which causes a shift in absorption to longer wavelengths. At these longer wavelengths, the problems encountered with erratic blank determinations are eliminated.

It is possible to use either of the above analyses, depending upon the availability of instrumentation and the concentrations being encountered.

The tests to determine the amount of blowoff and the amount of mass lost by aeration were included to account for possible mass losses that might be encountered during field testing. Since these losses appeared negligible and an average mask efficiency of about 80% for this smoke has been demonstrated, the complete system of mask and grenade appears to be adequate for use in the field tests for which it was devised.

Although the efficiency of the puff grenade varied, it averaged about 10%. Variation in efficiency of grenade dissemination is not unusual and may be caused by numerous factors, such as incomplete combustion of smoke mixture on ignition, combustion of a portion of the Uvinul during functioning, losses through openings in the test chamber, ejection of particles of the unreacted pyrotechnic mixture on the floor, and nonuniformity of the cloud being sampled. Probably the largest cause of variation was the individual differences between grenades, because they were all hand-mixed and packed in small lots. If they are manufactured on a production-line basis, the grenades should be much more uniform. This uniformity should decrease the variations in functioning between grenades.

The linear velocities used in these tests represent typical breathing rates through the oronasal mask, ranging from those of personnel at rest to those of personnel involved in moderate work. Under these conditions, filtration efficiency of the type-5 paper appeared to remain constant with changes in linear velocity.

V. CONCLUSIONS.

It was concluded that the "puff"-type grenade-oronasal mask system provides a technically feasible method for quantitatively evaluating the inhalation effectiveness of the cloud which would be produced by CW munitions. The system could be employed as part of the CARAMU program.

APPENDIXES

TABLE 1

EXPERIMENTAL RESULTS

Test	Date	Smoke grenade	Linear velocity	Average smoke concentration in chamber	Average weight of agent per type-5 filter	Number of samples	Average weight of agent per E 9 filter	Efficiency of type-5 filter	Grenade efficiency	Mass median diameter of smoke (cascade impactor)
			cm/min	μg/ℓ	μg		μg		%	μ
1	10/25/57	Uvinul M40	80	14	821	5	136	85	18	—
2	12/17/57	Uvinul 400	80	18	771	5	153	83	20	—
3	12/18/57	Uvinul 400	80	15	628	5	135	82	17	—
4	1/16/58	Uvinul 400	80	7.6	272	5	64	76	8.9	—
5	1/16/58	Uvinul 400	80	7.3	233	5	51	82	10	—
6	1/17/58	Uvinul 400	80	7.8	376	5	72	84	11	—
7	2/28/58	Uvinul 400	65	7.5	455	12	123	79	10	0.1
8	3/7 /58	Uvinul 400	65	3.4	263	12	47	85	6	0.1
9	3/10/58	Uvinul 400	65	8.2	420	12	88	83	10	0.5
10	3/11/58	Uvinul 400	65	9.2	424	12	167	72	14	0.5
11	4/3 /58	Uvinul 400	680 100	3.7 3.7	376 371	3 4	79 59	83 86	10	0.1 0.1
12	4/8 /58	Uvinul 400	1,000	3.5	366	4	70	85	7.4	0.1, 0.2
13	4/10/58	Uvinul 400	1,000	9.0	891	5	135	87	12	0.4, 0.5
14	4/15/58	Uvinul 400	1,000	12	1,098	5	282	79	17	0.5, 0.5
15	4/16/58	Uvinul 400	80	13	766	10	132	85	16	0.5, 0.7
16	4/18/58	Uvinul 400	1,000	19	1,392	5	339	80	29	0.1
17	4/23/58	Uvinul 400	100	7.7	253	8	118	68	11	0.4
18	8/8/ 58	Uvinul 400 (stored for 102 days at 130°F)	313	8.2	760	2	148	84	10	—
19	8/11/58	Uvinul 400 (stored for 102 days at 130°F)	313	11	1,188	2	198	86	13	—
20	8/12/58	Uvinul 400 (stored for 102 days at 130°F)	313	9.2	655	2	253	72	11	—
21	10/9/ 58	Uvinul 400 (stored for 45 days at ambient temp)	313	6.7	1,698	2	180	91	8.4	—
22	10/10/58	Uvinul 400 (stored for 46 days at ambient temp)	313	4.1	978	2	118	89	5.3	—
23	10/13/58	Uvinul 400 (stored for 49 days at ambient temp)	740	3.3	1,100	2	120	90	4.2	—
24	10/15/58	Uvinul 400 (stored for 51 days at ambient temp)	313	4.5	803	2	118	87	5.5	—
25	10/[illegible]/58	Uvinul 400 (stored for 75 days at ambient temp)	156 520 420 210 1,810 570	4.8	124 280 990 720 500 500	4 3 1 1 1 1	30 45 140 80 45 55	80 86 88 90 92 90	6.3	—

TABLE 2

VARIATION OF AIR INTAKE WITH BODY REQUIREMENTS*

Position	Frequency of inhalations per min	Volume inhaled in each breath		Exhalation rate		Inhalation rate	
		l	cu ft	l/min	cu ft/min	l/min	cu ft/min
Lying	14	0.35	0.01	4.9	0.17	6	0.20
Sitting	18	0.40	0.01	7.2	0.25	7	0.24
Standing	—	—	—	—	—	8	0.27
Walking 2 mph	—	—	—	—	—	14	0.48
Walking 85 paces per min	20	0.75	0.025	15	0.6	—	—
Walking 4 mph	—	—	—	—	—	26	0.89
Walking 125 paces per min	23	1.4	0.048	32	1.1	—	—
185 paces per min	24	1.7	0.06	41	1.4	—	—
Walking upstairs 85 steps per min	24	1.7	0.06	40	1.4	—	—
Running	—	—	—	—	—	43	1.47
Running fast 220 paces per min	40	2.05	0.07	82	2.8	—	—
Running upstairs 111 steps per min	40	2.1	0.08	84	2.9	—	—

*Data regarding the amounts of air breathed by man were compiled from two tables in Pieters, H. A. J., and Creyghton, J. W. Safety in the Chemical Laboratory. pp 40 and 41. Academic Press, Inc. 1951.

APPENDIX B

ANALYTICAL METHODS

Method 1

Analysis of Uvinul 400 by Klett-Summerson Colorimeter

Chemical Test for Uvinul 400

Solutions:

1. Isopropanol (reagent grade), 99.9%

2. Phosphate buffer solution: A volume of 0.1 M KH_2PO_4 solution adjusted to pH 7 by addition of 0.1 M NaOH

3. Naphthanil Diazo Blue B, 0.4% solution, in H_2O

4. Glacial acetic acid

Procedure:

Dissolve sample in measured amount of isopropanol. Filter sample. To 1 ml of filtered sample add 1 ml of buffer, and then add 1 ml of dye solution. Wait 15 minutes from addition of dye, add 2 ml of glacial acetic acid, and then measure on colorimeter with a no. 50 filter. Since the dye solution is unstable, it should be made fresh each day. This solution should be kept in a bottle wrapped in paper (e.g., aluminum foil) or kept in a dark location. Graph of knowns is run with each new batch of dye.

Calculate results in micrograms per sample.

Method 2

Analysis of Uvinul 400 by Beckman Spectrophotometer
(Improved method recommended for analysis)

Chemicals.

1. Approximately 0.1 N NaOH (filtered through Whatman paper)

2. Isopropanol (reagent grade), 99.9%

Equipment.

1. Beckman spectrophotometer (set at a slit opening of 0.19 mm and a wavelength of 350 mμ)

2. 250-ml Erlenmeyer flasks with stoppers

3. Funnels

4. Whatman paper no. 41

5. 1-ml pipets

6. Beckman cells (quartz)

Procedure.

1. Place sample of type-5 filter paper (containing Uvinul 400) in a 250-ml Erlenmeyer flask.

2. Add 99 ml of isopropanol.

3. Stopper flask and shake until paper is macerated.

4. Decant liquid into a funnel lined with Whatman paper no. 41.

5. Recover the filtrate and add 1 ml of the 0.1 N NaOH solution.

6. Read in Beckman spectrophotometer.

Note: Standardize Beckman spectrophotometer using isopropanol as blank.

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An instantaneously functioning grenade that disseminates 2, 4-dihydroxy benzophenone as an aerosol is discussed. The aerosol it produces can be used in conjunction with the oronasal mask to determine inhalation dosage of CW agents.

1. Caramu
2. 2, 4-Dihydroxy Benzophenone
3. Grenade, puff

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